Technical tips for fixation of proximal humeral fractures in elderly patients

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Despite the application of modern locking plate technology, complications remain common after fixation of proximal humeral fractures in elderly patients. Varus deformity and intra-articular hardware are most often responsible; fortunately, both of these complications can be avoided. Recent advances in imaging, reduction techniques, fixation methods, and postoperative care have made surgical outcomes more reliable. Particular attention should be paid to obtaining high-quality fluoroscopic images, avoiding varus reductions, supporting the osteoporotic humeral head, using appropriate screw length, using tension band sutures liberally, and protecting the construct postoperatively. Using these methods, many proximal humeral fractures in patients older than 75 years can be fixed reliably.

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Introduction

Interest in the fixation of proximal humeral fractures has grown worldwide in the past several years. This change in practice has been fueled by the recognition that humeral head replacement after an acute fracture has an unpredictable outcome; [1] an understanding that post-traumatic osteonecrosis of the humeral head is not a clinical disaster; [2] more accurate preoperative imaging using three-dimensional computed tomography (CT) scans; improvements in intraoperative imaging using fluoroscopy; refined reduction maneuvers; [3–5] and improved implants, in the form of contoured locking plates. Despite these advances, clinical results continue to be inconsistent, and the reported rates of surgical complications remain far too high [6–10]. Most reported revision procedures are necessitated by varus reduction [11] or screw penetration beyond the subchondral bone of the humeral head, [7] both of which can be avoided with good surgical techniques.

Indications

Neer's guidelines, published almost 40 years ago, remain useful [12,13]. Minimally displaced one-part fractures are treated nonsurgically. Most displaced fractures are typically treated with surgery. However, if the anticipated demands on the extremity are very low, it is reasonable to allow a displaced fracture to malunite and accept the motion loss caused by tuberosity impingement. Most two-part and three-part fractures can be fixed reliably using modern methods, even in patients with poor bone quality. Some four-part fractures can also be treated with open reduction and internal fixation (ORIF) [10,14,15]. It was suggested recently that the outcome of a properly performed osteosynthesis may be better than that of humeral head replacement [10].

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Preoperative planning

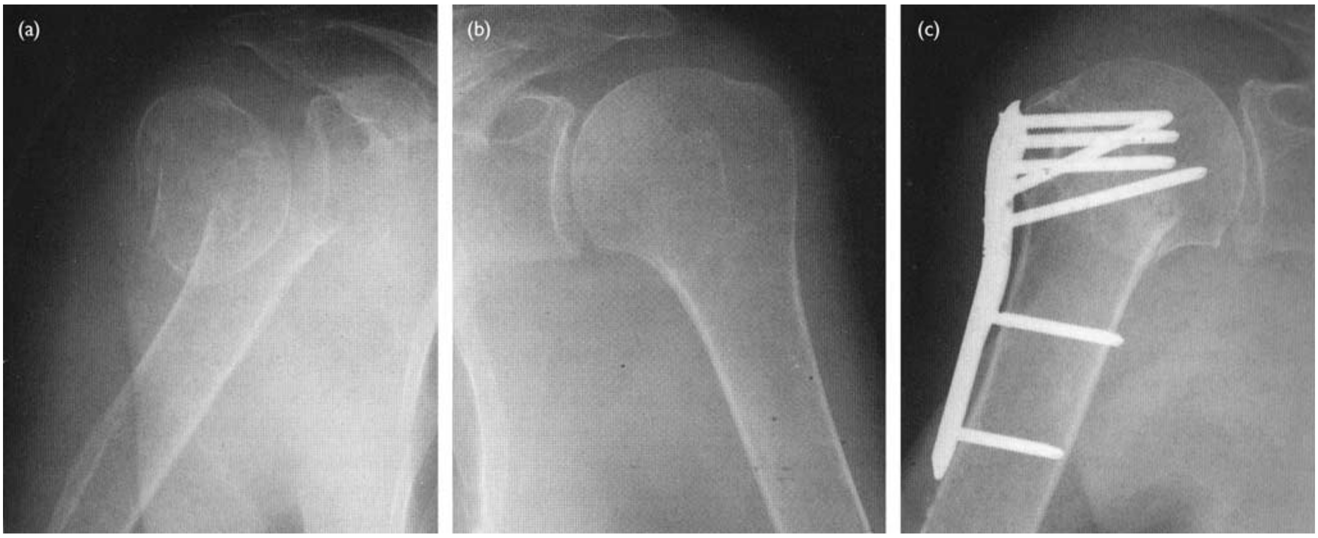
Good surgical results begin with a sound preoperative plan. A comparison radiograph of the opposite shoulder is valuable for intraoperative assessment of the quality of the reduction (Fig. 1), especially to avoid varus malreduction (one of the most common complications after ORIF) [4,7,10,11,16].

Three-dimensional CT scans can also be useful for understanding the geometry of more complex fractures and fracture dislocations. Subtraction views show bony Bankart lesions and articular fractures of the humeral head that may be difficult to detect on some two-dimensional images. For a three-part or four-part fracture, three-dimensional CT also shows what, if any, part of the greater or lesser tuberosity is attached to the head segment. Any area of continuity between the tuberosities and head segment may serve as a 'handle' to indirectly reduce the head segment with traction sutures placed at the bone–tendon junction of the rotator cuff (the so-called string puppet reduction technique). The use of three-dimensional CT has made it possible to plan the surgical exposure, reduction maneuvers, and hardware positioning and to anticipate the need for bone grafting (Fig. 2).

Surgical technique operating room setup for fluoroscopic imaging

The optimal operating room setup allows unrestricted access to the shoulder for fluoroscopic imaging. Most surgeons prefer using a standard operating table and some variation of the familiar beach chair patient position. The table is turned 90° after induction of anesthesia, so that the injured shoulder is opposite the anesthesia team and the equipment. This position allows the C-arm to enter and exit the field from the head of the operating table. Irrespective of the setup and patient positioning, it is wise to verify that a minimum of two high-quality fluoroscopic views can be obtained before draping

Figure 1



A two-part proximal humeral fracture in a 95-year-old woman. (a) Preoperative AP radiograph. (b) AP radiograph of the contralateral shoulder with the arm in external rotation. This comparison view serves as a template for reduction. (c) AP external rotation radiograph taken at follow-up. Despite shortening to gain stability, the neck-shaft angle and the position of the greater tuberosity were restored. AP, anteroposterior.

(Fig. 3). This step is critical for the prevention of intraoperative screw penetration.

Exposure

The extended deltopectoral approach is preferred because of the options for extensile exposure to address almost any proximal humeral fracture pattern, including fracture dislocations. The interval from the clavicle to the deltoid insertion is developed, while preserving the muscle origin and releasing a portion of the insertion as needed. The subdeltoid space is mobilized with care to avoid the terminal branches of the axillary nerve. A brown deltoid retractor is placed. Abduction of the arm relaxes the deltoid and allows access to the entire greater tuberosity and rotator cuff [17]. During the exposure and placement of hardware, every attempt is made to respect the primary blood supply to the humeral head by avoiding the anterior circumflex vessels as they course along the subscapularis and the arcuate artery as it courses along the bicipital groove.

Extensile maneuvers

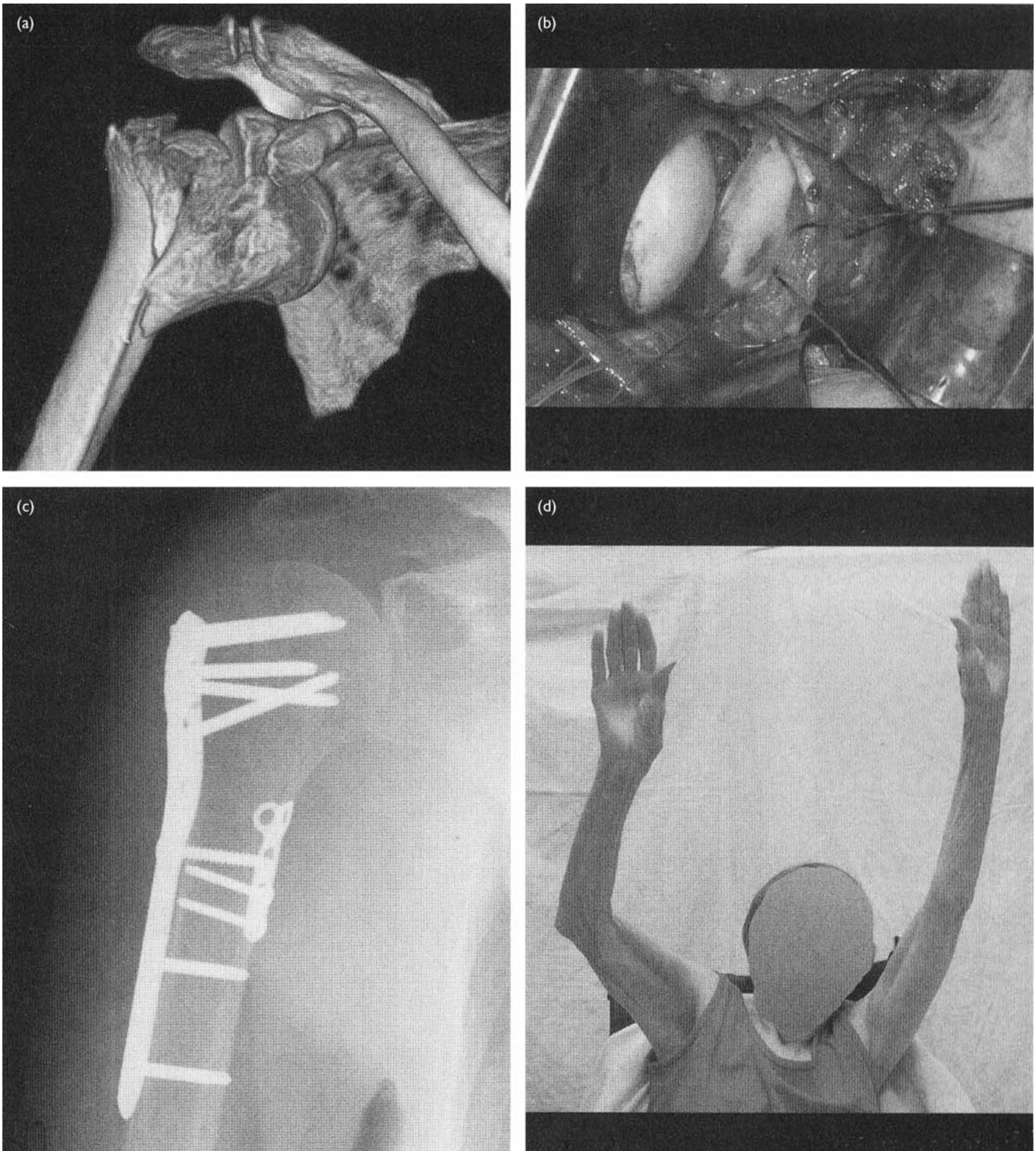
Fractures of the proximal humerus occasionally extend into the diaphysis. For this pattern, the exposure is carried distally (the Henry approach) and a long plate is applied to the lateral aspect of the humerus. In this situation, the deltoid insertion is released, but doing so does not appear to have any clinical sequelae, in the absence of a brachial plexopathy [18]. Conversely, dissection can be extended proximally and medially to enter the glenohumeral joint so that a humeral head articular fracture or a glenoid rim fracture can be treated. In patients with neurovascular injury, the brachial plexus and axillary artery can be explored through the deltopectoral interval.

Reduction maneuvers

Reduction maneuvers are determined by the fracture pattern. Impacted fractures are elevated using the method described by Jakob *et al.* [5] (Fig. 4). Unimpacted fractures are compressed using the 'parachute technique' described by Banco *et al.* [3] (Fig. 5). A valgus impaction osteotomy allows balanced compression of the head segment on the shaft. This technique relies on tension band sutures and is ideally suited for reducing two-part surgical neck fractures. The method can also be used to reduce three-part fractures if the anterior portion of the greater tuberosity is connected to the head segment.

Although the principles of the parachute technique can be applied to most proximal humeral fractures, contraindications do exist. The reduction method is dependent on an intact rotator cuff and cannot be used in fractures in which the tuberosities are detached from the head segment, impacted fracture patterns, and fractures with severe metaphyseal comminution. In fractures with metaphyseal comminution, the parachute technique can result in excessive humeral shortening and inferior instability. In these cases, humeral length can be restored with bone grafting. Options for bone graft material include autograft, allograft, or a synthetic substitute [4]. Restoration of humeral length is also important in treating complex anterior fracture dislocations in which the proximal humerus and glenoid are fractured (Fig. 2). If humeral length is not restored, it can be difficult to keep the humeral head concentrically reduced in the postoperative period. This situation is particularly problematic in patients with an associated axillary nerve injury.

Figure 2

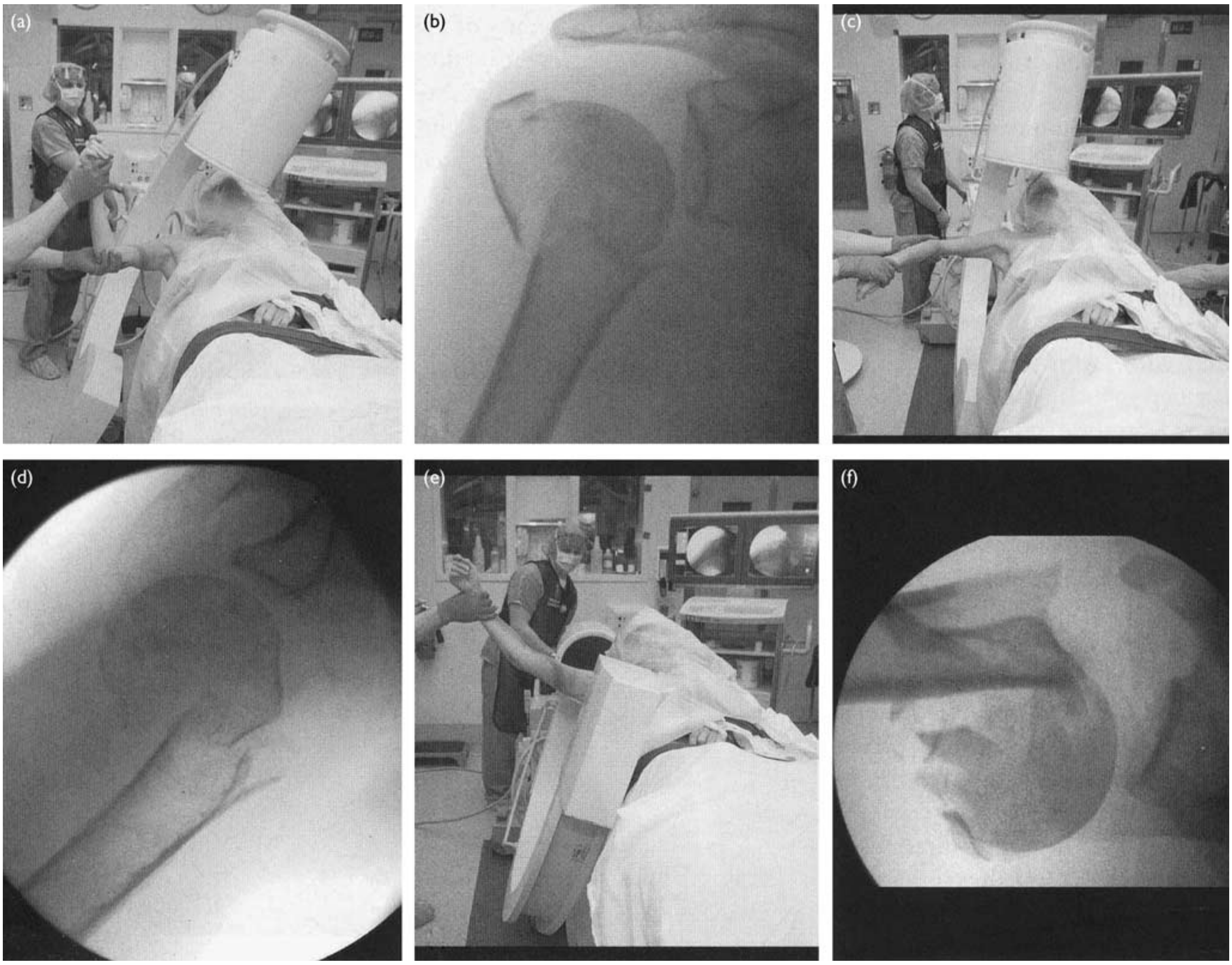


(a) Three-dimensional CT scan showing a fracture dislocation of the proximal humerus in an 87-year-old woman. The CT scan was used in planning the surgical exposure and positioning the implants. (b) Intraoperative photograph showing an anterior arthrotomy for access to the glenoid rim fracture and placement of transosseous sutures. (c) Postoperative AP radiograph showing the placement of a minifragment an-tiglide plate along the medial aspect of the humerus; the pectoralis major tendon was divided and later repaired after the medial plate application. (d) Clinical photograph of the patient (taken at the 3-month follow-up) showing overhead elevation of the arm. AP, anteroposterior; CT, computed tomography.

Humeral head support

The concept of humeral head support has been emphasized by several authors [3,6,19]. Most often, the head segment is supported by the shaft of the humerus. If there is moderate or severe traumatic bone loss, a bone graft or a bone graft substitute is used. A soft humeral head supported only by rigid hardware tends to settle onto the metal. The result is secondary screw cutout, which is a frequently reported reason for revision surgery [7–10].

Figure 3



Fluoroscopic images are obtained in the operating room. (a) Photograph showing positioning of the device to direct the fluoroscopic beam perpendicular to the scapula, with the patient's arm held in external rotation. (b) An example of a preoperative AP external rotation fluoroscopic view. The relationship between the humeral shaft, the humeral head, and the greater tuberosity can be seen. (c) Operating room photograph of patient positioning for the Velpeau axillary view taken with the arm held in internal rotation and slight longitudinal traction. Gentle traction lateralizes the scapula away from the operating room table and the patient's head. This allows unobstructed imaging of the proximal humerus and glenoid. (d) An example of a preoperative Velpeau axillary internal rotation fluoroscopic view. Note the typical apex anterior angulation between the shaft and the head segment. (e) Operating room photograph showing patient positioning for the standard axillary view taken with the arm held in neutral rotation and longitudinal traction. (f) An example of a preoperative fluoroscopic axillary view. This view shows the position of the lesser tuberosity and the relationship of the humeral head with the glenoid. AP, anteroposterior.

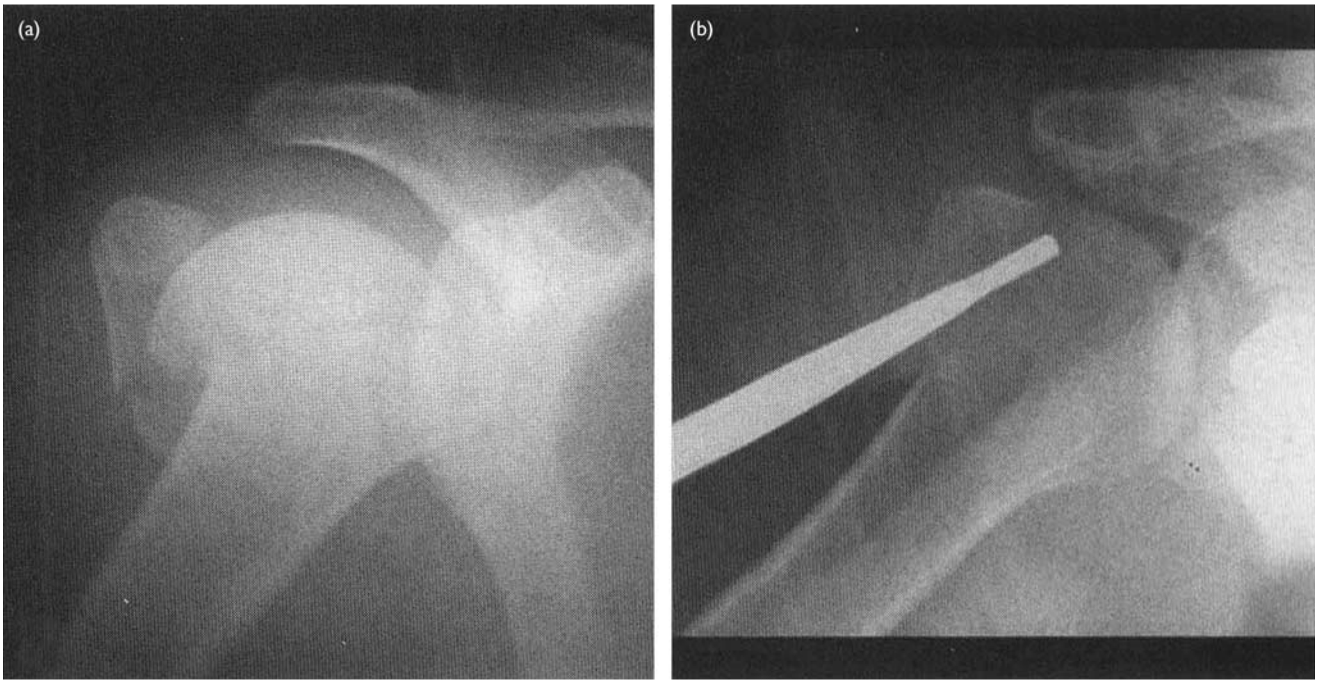
Provisional fixation

After the initial reduction, provisional fixation is achieved with a Steinmann pin or pins placed just posterior to the long head of the biceps tendon. This location avoids interference with the plate that will later occupy the lateral surface of the proximal humerus. The traction sutures are tensioned and tied to the pin (Fig. 6). This form of robust temporary tension band fixation allows the arm to be rotated so that the reduction can be assessed fluoroscopically in multiple planes.

Assessment of reduction

The position of the shaft, head, and tuberosities is assessed by high-quality fluoroscopic imaging. On the anteroposterior external rotation fluoroscopic view (Fig. 7), the shaft of the humerus should be under the humeral head, the greater tuberosity should be ~5–10 mm below the top of the head, and the articular surface should point toward the upper portion of the glenoid (R.H. Cofield, Rochester, Minnesota, personal communication, 1998). Additional precision can be gained by referencing the image of the opposite shoulder. A reasonable attempt should be made to match the tuberosity height and neck-shaft angle of the opposite shoulder. Additional fluoroscopic views are used as necessary to assess translation and angulation of the humeral shaft relative to the head, the position of the lesser tuberosity, and the position of the head segment relative to the glenoid. The course of the long head of the biceps tendon is checked to confirm the rotational accuracy of the reduction. The provisional reduction should be scrutinized, and final adjustments should be

Figure 4



(a) AP radiograph showing a valgus-impacted four-part fracture. (b) Intraoperative fluoroscopic image showing elevation of the humeral head using a square-tipped impactor placed through a coronal split in the greater tuberosity. AP, anteroposterior.

made before the hardware is placed. The most common pitfall is the persistent varus position of the head segment. In most instances, this problem is easily resolved by slightly backing out the provisional Steinmann pin and adding additional provisional tension band sutures extending from the bone–tendon junction of the supraspinatus to the provisional pin.

Definitive fixation

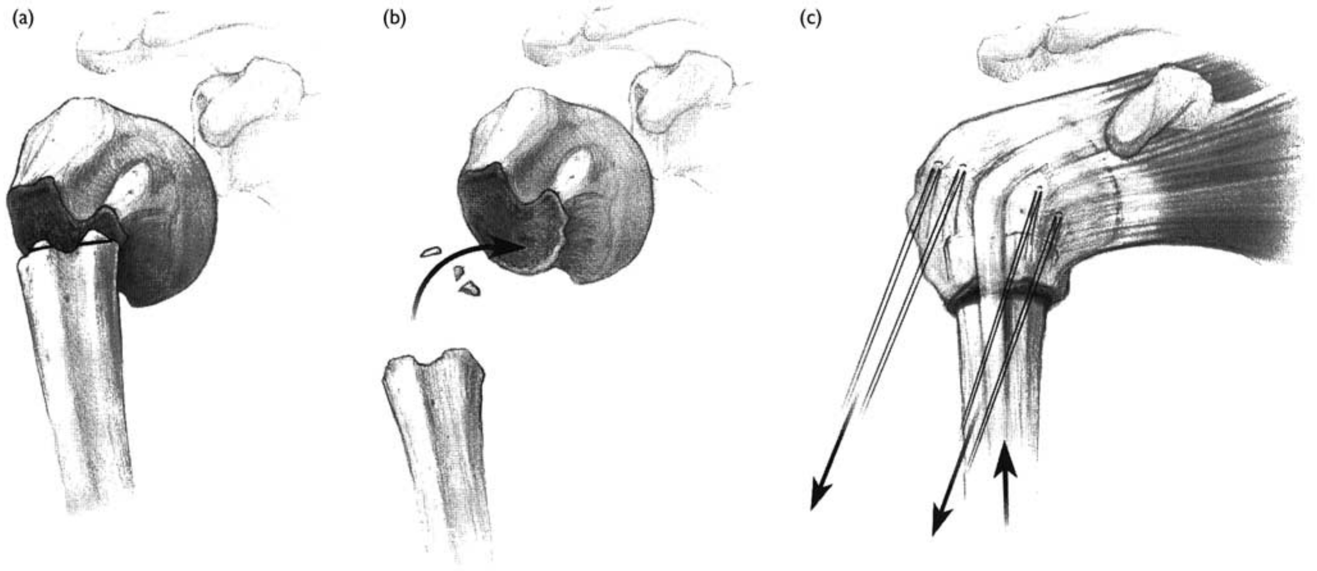
A precontoured locking plate is applied laterally (Fig. 8) and held with a push–pull reduction device (the so-called whirlybird). It is important to note that the plate is applied to the fracture after it is reduced and compressed. Hardware position is primarily assessed from the external rotation view (Fig. 9). If the plate is positioned too high, it will cause impingement; if it is too low, the screw trajectory may be suboptimal. Gaps between the plate and the bone in the metadiaphysis are acceptable, and no attempt is made to contour the plate. This technique is quite different from the use of the plate as a reduction tool. Pulling the bone to the plate with screws or sutures tends to leave the head unsupported and at risk for varus drift or secondary screw penetration [7,11]. When the plate position is optimal, screws are placed into the osteoporotic humeral head (Fig. 10). Because bone quality is often poor in this elderly patient population, only the outer cortex is drilled. The depth gauge is then inserted and gently advanced to the desired depth under fluoroscopic control. It is important to understand that if the head is supported and tension band sutures are used, the subchondral bone of the head need not be engaged. Placing shorter screws lowers the risk of screw penetration [7]. Following plate application, the provisional pin and suture fixation is removed. Next, definitive tension band sutures are placed using any open holes in the plate as anchor points (Fig. 11). It is preferable to use smooth holes to minimize the risk of suture abrasion.

Postoperative care

Experience with caring for very elderly patients suggests that cognitive impairment is common. Many patients older than 75 years have limited understanding of their condition and are unable to participate in the gentle, passive range-of-motion program used in younger patients with good bone quality. In elderly patients, aggressive range-of-motion and strengthening exercises performed before union of the fracture may increase the risk of fixation failure. With these concerns in mind, a variation of Neer's limited goals rehabilitation program seems appropriate for this patient population [1,17]. The primary focus of the program is protection of the fixation construct. Motion and strength are restored gradually over months.

During the first 6 weeks after surgery, patients are directed to wear a sling full time. After 6 weeks, supine active assisted range-of-motion exercises are initiated. Radiographs taken 12 weeks after surgery usually show fracture consolidation (Fig. 12). At this point, use of the sling is discontinued and the patient is encouraged to use the arm for light daily activities, including driving and shopping. More forceful activities, such as yard work, tennis, and golf, are avoided for 6 months.

Figure 5



Schematic drawings showing a modification of the valgus impaction osteotomy. (a) The transverse line delineates the intended level of the osteotomy. Prominent edges of the shaft anteriorly and laterally are trimmed with a rongeur to create a relatively flat surface that will allow balanced compression of the head segment. (b) The 'trimmings' are placed into the head segment and function as a local bone graft. (c) The head segment is supported by upward impaction of the shaft. The position of the head segment is adjusted with traction sutures placed at the bone–tendon junction of the subscapularis and supraspinatus tendons. Reproduced with permission from the Mayo Foundation of Medical Education and Research, Rochester, Minnesota, USA.

Results

General

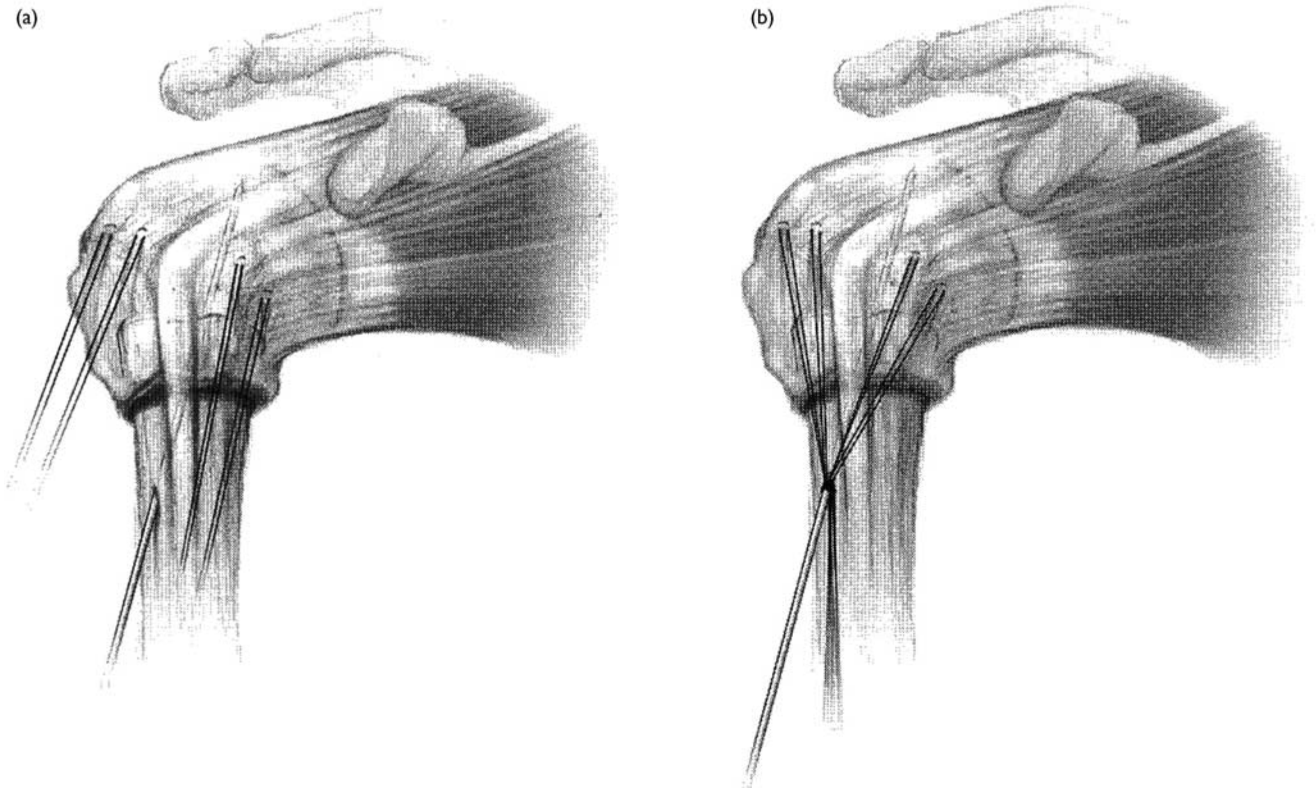
There are few studies in the literature on the topic of proximal humeral fracture fixation in elderly patients [3,7,10,16,20]. Hintermann *et al.* [20] reported on 42 patients older than 50 years with three-part and four-part humeral fractures who were treated with internal fixation with a blade plate. Although fracture healing was reliable, [11] secondary procedures were needed mainly to treat postoperative stiffness and prominent hardware. The authors advocated primary open reduction of all three-part and four-part humeral fractures irrespective of the patient's age.

Banco *et al.* [3] reviewed outcomes of a valgus impaction osteotomy for treatment of two-part fractures. Thirteen patients with a mean age of 68 years were treated with the parachute technique using Dacron tapes as tension band sutures. All fractures healed after an average of 45 days. There were no reported complications or resurgeries. The authors concluded that the use of this technique to treat two-part fractures in elderly patients with osteopenic bone eliminates the morbidity of hardware implantation.

More recently, the results of locked plating for proximal humeral fractures in older patients have become available. Solberg *et al.* [10] reported on a group of 70 patients older than 55 years with three-part and four-part humeral fractures. The patients were treated using a technique that involved the placement of screws within 5 mm of the subchondral bone of the humeral head. Active assisted range of motion was initiated postoperatively after 10 days. After 6 weeks, unrestricted motion and strengthening was allowed. Five patients had early return to the operating room for revision because of screw penetration of the humeral head seen on postoperative radiographs. By the 18-month follow-up, an additional 29 patients required reoperation for complications such as secondary screw perforation, fixation failure, and osteonecrosis. The authors reported a particularly poor prognosis associated with varus reductions. Late subsidence developed in all fractures that had more than 5° of varus malreduction.

Two large multicenter studies from Europe also reported frequent complications with locked plating for proximal humeral fractures [7,16]. Brunner *et al.* [7] reported the results from eight centers in Switzerland, where 158 fractures were treated by 53 surgeons between 2002 and 2005. The average age of the patients was 65 years, and 71% were women. At the 1-year follow-up, 71 complications had been reported and 25% of the patients required reoperation. The most common cause for reoperation was screw perforation into the glenohumeral joint. Patients older than 60 years were more likely to have a complication than younger patients. The authors recommended using shorter screws, more accurate measurement of screw length, and more frequent use of tension band sutures to neutralize the deforming forces of the rotator cuff. In a similar study, Südkamp *et al.* [16] reported the results of 187 patients with proximal humeral fractures treated in nine German centers between 2002 and 2005. The fractures were treated with ORIF and a locking proximal humeral plate. The average patient age was 62.9 years, and 72% were women. The

Figure 6



Schematic drawings showing a method of provisional fixation of proximal humeral fractures using pin and tension band suture fixation. This form of robust provisional fixation allows rotation of the arm for high-quality fluoroscopic imaging to assess the reduction in multiple planes. (a) A long Steinmann pin is placed from the shaft into the head segment. (b) Traction sutures are tensioned and tied to the pin. Tensioning the sutures pulls the head segment out of varus. Reproduced with permission from the Mayo Foundation of Medical Education and Research, Rochester, Minnesota, USA.

postoperative regimen involved early active range-of-motion exercises. Complications occurred in 34% of the patients, and 19% required reoperation. Again, many of the complications were related to primary screw penetration, varus reductions, and the placement of screws too close to the subchondral bone of the humeral head. The authors concluded that it was important for surgeons to use proper surgical techniques to avoid iatrogenic errors.

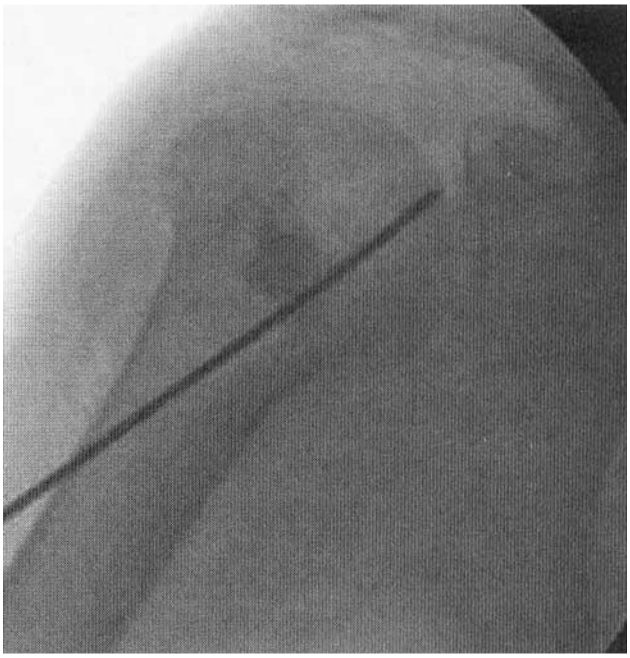
Mayo clinic

The results of the Mayo Clinic's first 16 cases of locked plating for proximal humeral fractures were reported by Rose *et al.* [6] in 2007. Similar to other studies, a high rate of reoperation (19%) was reported. Surprisingly, older patients seemed to fare better than younger patients. This incidental finding prompted a critical analysis of the results. When the treatment of older patients was compared with the treatment of younger patients, four major differences were ascertained. (a) In most cases, elderly patients had been treated with a nonanatomic reduction using a valgus impaction osteotomy [3]. (b) In older patients, a greater emphasis was placed on supporting the humeral head with the proximal humeral shaft or bone graft [3,4] (c) Tension band sutures were used liberally in all older patients to neutralize the forces of the rotator cuff. (d) In older patients with poor bone quality, the fixation was protected by delaying range-of-motion exercises for a period of 6 weeks [1,17]. This protocol has been called the hybrid technique because concepts from multiple sources were combined with modern locking plate technology. Results using the hybrid technique have been promising.

Hybrid technique

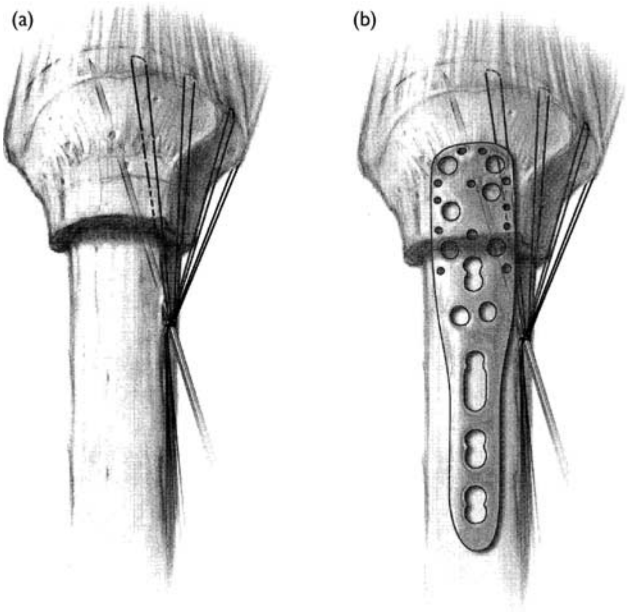
During a 5-year period (2002–2007), the author used the hybrid protocol to treat 23 consecutive patients (mean age 84 years; range 75–97 years) with displaced proximal humeral fractures. The results were reviewed after a minimum of 1 year (range 12–36 months; mean 28 months). There were 10 Neer two-part fractures of the surgical neck, 10 Neer three-part fractures involving the surgical neck and greater tuberosity, and three severely impacted patterns as described by Jakob *et al.* [5]. At follow-up, all fractures healed, and all patients were able to perform daily activities independently. The mean elevation was 140° and the mean external rotation was 42°. There were no cases of screw perforation, fixation failure, osteonecrosis, or infection. No reoperations were necessary in this group. The data suggest that advanced age is not a contraindication to ORIF and a brief period of postoperative immobilization does not appear to cause disabling stiffness in elderly patients.

Figure 7



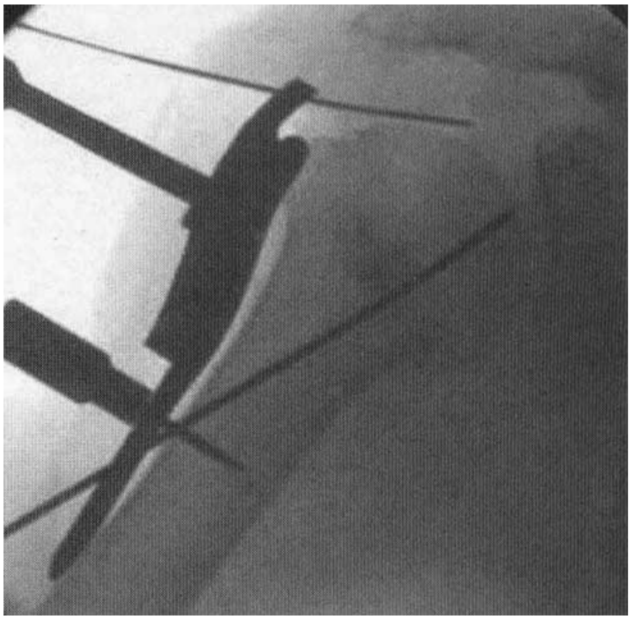
External rotation fluoroscopic image showing a provisional reduction of a three-part humeral fracture with a Steinmann pin and tension band sutures. A small amount of bone graft substitute was used to help support the humeral head.

Figure 8



Schematic drawings showing a lateral view of the proximal humerus after provisional fixation. Note that the position of the pin and sutures (a) allows unobstructed access for definitive fixation with a precontoured locking plate (b). Reproduced with permission from the Mayo Foundation of Medical Education and Research, Rochester, Minnesota, USA.

Figure 9



AP external rotation view fluoroscopic image showing plate positioning below the top of the humeral head. AP, anteroposterior.

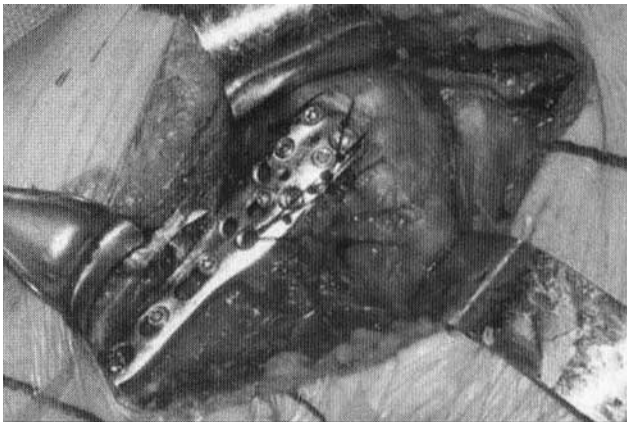
Figure 10

AP fluoroscopic image showing a method of screw placement that minimizes the risk of primary or secondary penetration. The arm is rotated under the fluoroscopy machine to check screw length in multiple planes. AP, anteroposterior.

Summary

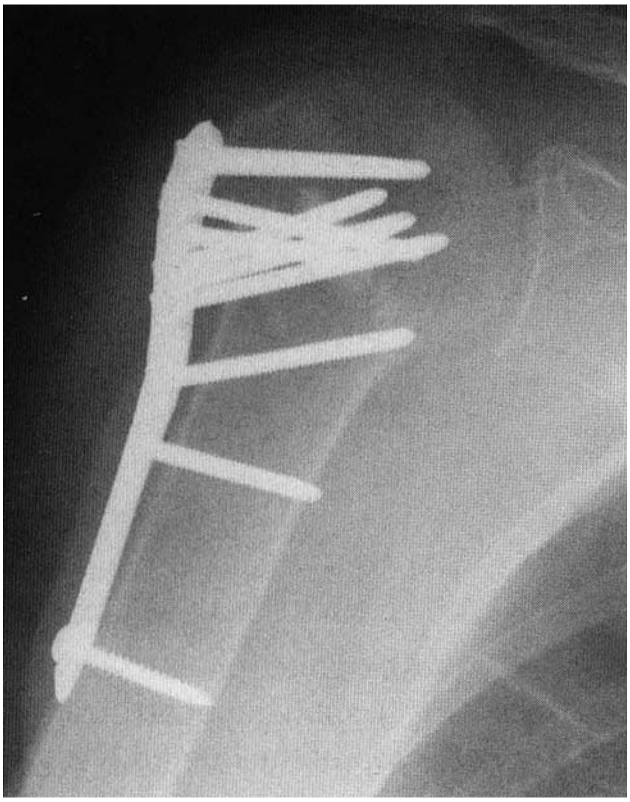
With a sound preoperative plan and attention directed to good surgical technique, many proximal humeral fractures in elderly patients can be fixed reliably. The key elements to successful treatment include high-quality fluoroscopic imaging, an accurate reduction, support of the humeral head, locking plate fixation, generous tension band suturing, and postoperative protection of the construct.

Figure 11



Intraoperative photograph showing the final construct. Heavy monofilament absorbable tension band sutures are applied liberally using empty holes in the plate as anchor points.

Figure 12



A typical 3-month follow-up AP external rotation radiograph of the proximal humerus showing consolidation of the fracture.

Acknowledgements

Conflicts of interest

Neither Dr Torchia nor an immediate family member has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this chapter.

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